Coupling damage-sensing particles and computational micromechanics to enable the digital twin concept

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Purpose

The concept vehicles that will enable future missions must be designed for conditions which may not be repeatable in the lab, and will likely experience loads and environments that were not foreseen during the design phase. This raises two issues: 1) Certification - by test - may not be possible under the current method. 2) Unexpected, and individually-experienced loads and environments modify the expected life, necessitating a management method in which the limit loads decrease throughout each vehicle's service life. The first purpose of this research is to develop a material with inherent damage sensing capability to ease the necessity of certification by test in extreme cases. The second purpose is to develop a methodology whereby the as-built vehicle state, as-experienced loads and environments, and other vehicle-specific history will be used to enable high-fidelity modeling of individual vehicles throughout their service lives.

Background

State-of-the-art vehicle fleet management has limited accuracy since reliability calculations are based on a single, idealized worst-case model. Such estimates are then applied to all vehicles in a fleet, independent of any one vehicle's as-built conditions, loading, and environmental conditions. However, no two components within a fleet are equivalent in as-built geometry or material, and no two vehicles experience equivalent usage or environment during their lifetime. This assumption of representative, worst-case conditions leads to two potential issues: 1) costly inspection or replacement of parts which contain no damage and 2) underestimating loads and damage evolution, thereby overestimating vehicle reliability.

The proposed combination of sensory particles to detect damage, and better-informed computational simulations for damage prognosis would significantly reduce uncertainty in the management of aero-vehicles. Rather than a single predetermined inspection schedule, the proposed technology would provide vehicle-specific condition-based inspection intervals, providing a significant reduction in the cost of inspection and maintenance. Using damage-sensing particles in components under high-cycle fatigue would allow damage tolerance approaches to be applied much earlier in the vehicle life, which would revolutionize the way aircraft fleets are managed. This approach could be applied to modern-military and future concept vehicles alike.